


Form PTO-1390 (REV 10-95)	U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER 388-011500
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		U.S. APPLICATION NO. (If known, use 35 CFR 1.5) 09/914994
INTERNATIONAL APPLICATION NO. PCT/JP99/01083	INTERNATIONAL FILING DATE 05.03.99 (March 05, 1999)	PRIORITY DATE CLAIMED 05.03.99 (March 05, 1999)
TITLE OF INVENTION SYSTEM AND METHOD FOR REMOVING CARBON MONOXIDE		
APPLICANT(S) FOR DO/EO/US Mitsuaki ECHIGO, Minoru SUZUKI and Osamu OKADA		
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:		
<p>1. <input checked="" type="checkbox"/> This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.</p> <p>2. <input type="checkbox"/> This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.</p> <p>3. <input checked="" type="checkbox"/> This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1)</p> <p>4. <input checked="" type="checkbox"/> A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date</p> <p>5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2))</p> <p>a. <input type="checkbox"/> is transmitted herewith (required only if not transmitted by the International Bureau).</p> <p>b. <input checked="" type="checkbox"/> has been transmitted by the International Bureau.</p> <p>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US).</p> <p>6. <input checked="" type="checkbox"/> A translation of the International Application into English (35 U.S.C. 371(c)(2)).</p> <p>7. <input checked="" type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))</p> <p>a. <input type="checkbox"/> are transmitted herewith (required only if not transmitted by the International Bureau).</p> <p>b. <input type="checkbox"/> have been transmitted by the International Bureau.</p> <p>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired</p> <p>d. <input checked="" type="checkbox"/> have not been made and will not be made</p> <p>8. <input type="checkbox"/> A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).</p> <p>9. <input checked="" type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).</p> <p>10. <input checked="" type="checkbox"/> A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).</p> <p>Items 11. to 16. below concern document(s) or information included:</p> <p>11. <input type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.</p> <p>12. <input checked="" type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.</p> <p>13. <input checked="" type="checkbox"/> A FIRST preliminary amendment.</p> <p><input type="checkbox"/> A SECOND or SUBSEQUENT preliminary amendment.</p> <p>14. <input type="checkbox"/> A substitute specification.</p> <p>15. <input type="checkbox"/> A change of power of attorney and/or address letter.</p> <p>16. <input checked="" type="checkbox"/> Other items or information:</p> <p>a. WO 00/53696-Front Page with Abstract and Search Report (3 pp.)</p> <p>b. English translation of IPER and Amendments Under Article 34 (13 pp.)</p>		

U.S. APPLICATION NO. 09/914994		INTERNATIONAL APPLICATION NO. PCT/JP99/01083		ATTORNEY'S DOCKET NUMBER 388-011500	
17. <input checked="" type="checkbox"/> The following fees are submitted: BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5)):				CALCULATIONS PTO USE ONLY	
Search Report has been prepared by the EPO or JPO.....				\$860.00	
International preliminary examination fee paid to USPTO (37 CFR 1.482).....				\$690.00	
No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)).....				\$710.00	
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO.....				\$1,000.00	
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4).....				\$100.00	
ENTER APPROPRIATE BASIC FEE AMOUNT =				\$ 860.00	
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e))				\$ 0.00	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	22 - 20	2	X \$18.00	\$ 36.00	
Independent claims	2 - 3 =	0	X \$80.00	\$ 0.00	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ \$270.00	\$ 0.00	
TOTAL OF ABOVE CALCULATIONS =				\$ 896.00	
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28).				\$ 0.00	
SUBTOTAL =				\$ 896.00	
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f))				\$ 0.00	
TOTAL NATIONAL FEE =				\$ 896.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) \$40.00 per property				\$ 40.00	
TOTAL FEES ENCLOSED =				\$ 936.00	
				Amount to be refunded	\$
				charged	\$
<p>a. <input checked="" type="checkbox"/> A check in the amount of \$ 936.00 to cover the above fees is enclosed</p> <p>b. <input type="checkbox"/> Please charge my Deposit Account No. _____ in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed</p> <p>c. <input checked="" type="checkbox"/> The Assistant Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 23-0650. A duplicate copy of this sheet is enclosed.</p> <p>NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.</p> <p>SEND ALL CORRESPONDENCE TO: Russell D. Orkin 700 Koppers Building 436 Seventh Avenue Pittsburgh, Pennsylvania 15219-1818 Telephone: (412) 471-8815 Facsimile: (412) 471-4094</p> <p style="text-align: right;">  SIGNATURE Russell D. Orkin NAME 25,363 REGISTRATION NUMBER </p>					

PATENT APPLICATION/PCT
Attorney's Docket No. 388-011500

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of :
Mitsuaki ECHIGO, :
Minoru SUZUKI : **SYSTEM AND METHOD FOR**
and Osamu OKADA : **REMOVING CARBON MONOXIDE**
International Application :
No. PCT/JP99/01083 :
International Filing Date :
05 March 1999 :
Priority Date Claimed :
05 March 1999 :
Serial No. Not Yet Assigned :
Filed Concurrently Herewith :
Pittsburgh, Pennsylvania
September 5, 2001

PRELIMINARY AMENDMENT

BOX PCT
Commissioner for Patents
Washington DC 20231

Sir:
Prior to initial examination, please amend the above-identified patent application
as follows:

IN THE SPECIFICATION:

Please insert and amend section headings as follows. (Pursuant to 37 CFR
1.121, a marked-up version of the amended specification headings is attached.)

On original page 1, line 1, please delete the word "SPECIFICATION".

On original page 1, line 4, please insert the following section heading:

BACKGROUND OF THE INVENTION

On original page 1, line 5, please amend the section heading "TECHNICAL FIELD" to read as follows:

1. Field of the Invention

On original page 1, line 21, please amend the section heading "BACKGROUND ART" to read as follows:

2. Description of Related Art

On amended page 4, line 13, please amend the section heading "DISCLOSURE OF THE INVENTION" to read as follows:

SUMMARY OF THE INVENTION

On amended page 11, line 19, please amend the section heading "BEST MODE OF EMBODYING THE INVENTION" to read as follows:

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

On original page 15, line 1, please delete the section heading "EMBODIMENT".

On original page 23, line 16, delete the section heading "EFFECT OF THE INVENTION".

IN THE CLAIMS:

Original claims 1-11 were amended under Article 34 on January 4, 2000, at which time claims 1-9 were submitted. An English translation of the Amendments under Article 34 are attached to the papers being filed with the initiation of the National Phase of the above-identified PCT application.

Please cancel original claims 1-11 and cancel amended claims 1-9 and rewrite them as new claims 12-33 as follows:

12. A system for removing carbon monoxide from a hydrogen-containing treatment-object gas comprising two stages of CO removers for removing carbon monoxide, the first-stage CO remover removing a portion of the carbon monoxide by methanation thereof through a catalyst reaction by a first metal catalyst comprising one or more kinds selected from the group consisting of Ru, Pt, Rh, and Pd and capable of methanating carbon monoxide, the second-stage CO remover removing a remaining portion of the carbon monoxide mainly by oxidation thereof through a further catalyst reaction involving addition of an oxidizing agent.

13. The system for removing carbon monoxide, according to claim 12, wherein:
the first-stage CO remover includes the first metal catalyst and a first catalyst reaction condition setting mechanism for maintaining a catalyst reaction layer of the first-stage CO remover at a temperature required for methanation reaction of the carbon monoxide by the first metal catalyst; and

the second-stage CO remover includes a second metal catalyst capable of oxidizing the carbon monoxide, a second catalyst reaction condition setting mechanism for maintaining a catalyst reaction layer of the second-stage CO remover at a temperature required for the oxidation reaction of the carbon monoxide by the second metal catalyst, and an oxidizing-agent supplying mechanism for supplying the oxidizing agent required for the oxidation reaction with adjustment of the oxidizing agent addition amount.

14. The system for removing carbon monoxide, according to claim 12, wherein said treatment-object gas is a reformed gas obtained by reforming of fuel such as hydrocarbon, alcohol, naphtha, kerosene to be supplied as a fuel gas to a fuel cell.

15. A method of removing carbon monoxide from a hydrogen-containing treatment-object gas comprising:

a first step of causing the treatment-object gas to contact a first metal catalyst comprising one or more kinds selected from the group consisting of Ru, Pt, Rh, and Pd and capable of methanating carbon monoxide at a temperature where methanation of carbon monoxide takes place by the first metal catalyst so that a portion of the carbon monoxide is removed through carbon monoxide methanation; and

a second step of causing the treatment-object gas from the first step together with an oxidizing agent to contact a second metal catalyst capable of oxidizing carbon monoxide so that a remaining portion of carbon monoxide is removed mainly through carbon monoxide oxidation.

16. The method of removing carbon monoxide, according to claim 15, wherein in the first step, a reaction temperature of catalyst reaction between the first metal catalyst and the treatment-object gas is controlled to a temperature at which methanation of carbon monoxide may be promoted with restricting methanation of carbon dioxide, so as to reduce a carbon monoxide concentration of the treatment-object gas to approximately 50% or lower of an original carbon monoxide concentration of the treatment-object gas charged into this first step.

17. The method of removing carbon monoxide, according to claim 15, wherein in the second step, the second metal catalyst comprising one or more kinds selected from the group consisting of Ru, Pt, Rh and Pd is employed and

in the second step, a catalyst reaction layer is maintained at a temperature where oxidation of carbon monoxide takes place by the second metal catalyst involving addition of an oxidizing agent.

18. The method of removing carbon monoxide, according to claim 15, wherein a total amount of the oxidizing agent supplied at the second step is below about 3 chemical equivalents in oxygen conversion relative to an amount of carbon monoxide originally contained in the treatment-object gas introduced in the first step.

19. The method of removing carbon monoxide, according to claim 15, wherein a total amount of the oxidizing agent supplied at the second step is below the chemical equivalent in oxygen conversion relative to an amount of carbon monoxide originally contained in the treatment-object gas introduced in the first step.

20. The method of removing carbon monoxide, according to claim 15, wherein said hydrogen-containing treatment-object gas comprises a reformed gas supplied to a fuel cell as a fuel gas.

21. The system for removing carbon monoxide, according to claim 13, wherein said treatment-object gas is a reformed gas obtained by reforming of fuel such as hydrocarbon, alcohol, naphtha, kerosene to be supplied as a fuel gas to a fuel cell.

22. The method of removing carbon monoxide, according to claim 16, wherein in the second step, the second metal catalyst comprising one or more kinds selected from the group consisting of Ru, Pt, Rh and Pd is employed and

in the second step, a catalyst reaction layer is maintained at a temperature where oxidation of carbon monoxide takes place by the second metal catalyst involving addition of an oxidizing agent.

23. The method of removing carbon monoxide, according to claim 16, wherein a total amount of the oxidizing agent supplied at the second step is below about 3 chemical equivalents in oxygen conversion relative to an amount of carbon monoxide originally contained in the treatment-object gas introduced in the first step.

24. The method of removing carbon monoxide, according to claim 17, wherein a total amount of the oxidizing agent supplied at the second step is below about 3 chemical equivalents in oxygen conversion relative to an amount of carbon monoxide originally contained in the treatment-object gas introduced in the first step.

25. The method of removing carbon monoxide, according to claim 22, wherein a total amount of the oxidizing agent supplied at the second step is below about 3 chemical equivalents in oxygen conversion relative to an amount of carbon monoxide originally contained in the treatment-object gas introduced in the first step.

26. The method of removing carbon monoxide, according to claim 16, wherein a total amount of the oxidizing agent supplied at the second step is below the chemical equivalent in oxygen conversion relative to an amount of carbon monoxide originally contained in the treatment-object gas introduced in the first step.

27. The method of removing carbon monoxide, according to claim 17, wherein a total amount of the oxidizing agent supplied at the second step is below the chemical equivalent in oxygen conversion relative to an amount of carbon monoxide originally contained in the treatment-object gas introduced in the first step.

28. The method of removing carbon monoxide, according to claim 22, wherein a total amount of the oxidizing agent supplied at the second step is below the chemical equivalent in oxygen conversion relative to an amount of carbon monoxide originally contained in the treatment-object gas introduced in the first step.

29. The method of removing carbon monoxide, according to claim 16, wherein said hydrogen-containing treatment-object gas comprises a reformed gas supplied to a fuel cell as a fuel gas.

30. The method of removing carbon monoxide, according to claim 17, wherein said hydrogen-containing treatment-object gas comprises a reformed gas supplied to a fuel cell as a fuel gas.

31. The method of removing carbon monoxide, according to claim 18, wherein said hydrogen-containing treatment-object gas comprises a reformed gas supplied to a fuel cell as a fuel gas.

32. The method of removing carbon monoxide, according to claim 19, wherein said hydrogen-containing treatment-object gas comprises a reformed gas supplied to a fuel cell as a fuel gas.

33. The method of removing carbon monoxide, according to claim 22, wherein said hydrogen-containing treatment-object gas comprises a reformed gas supplied to a fuel cell as a fuel gas.

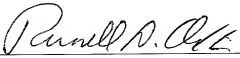
REMARKS

Original claims 1-11 and Amended claims 1-9 have been canceled by this Preliminary Amendment and rewritten as new claims 12-33.

Examination and allowance of claims 12-33 are respectfully requested.

Respectfully submitted,

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[illegible]

[TECHNICAL FIELD]

Original page 1, line 21 section heading

[BACKGROUND ART]

Amended page 4, line 13 section heading

[DISCLOSURE OF THE INVENTION]

SUMMARY OF THE INVENTION

Amended page 11, line 19 section heading

[BEST MODE OF EMBODYING THE INVENTION]

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

SPECIFICATION

SYSTEM AND METHOD FOR REMOVING CARBON MONOXIDE

5 TECHNICAL FIELD

10 The present invention relates to the technique of removing carbon monoxide contained in a hydrogen-rich reformed gas (an example of "treatment-object gas" as so referred to in the present application) such as obtained e.g. in the reforming process of hydrocarbon fuels including natural gas, naphtha, kerosene, etc, or alcoholic fuels such as methanol.

15 The technique to which the present application relates is characterized that it can remove carbon monoxide up to a concentration of ten ppm or lower. For this ability, the technique can be suitably employed in a power generating system using e.g. solid polymer electrolyte fuel cell which operates at a relatively low temperature.

For the purpose of simplifying the description, the following description will be made by taking a reformed gas used in a fuel cell as an example of the treatment-object gas.

20 BACKGROUND ART

Conventionally, with a fuel reforming apparatus using fossil fuel such as natural gas as raw fuel, a carbon monoxide shift converter is 25 connected to the downstream end of the reformer so as to convert carbon monoxide in the reformed gas into carbon dioxide by the water-gas shift reaction, whereby the carbon monoxide concentration is reduced (removed) to 1% approximately.

On the other hand, with a fuel reforming apparatus using methanol 30 as raw fuel, since this apparatus involves a step of the water-gas shift

reaction, the carbon monoxide concentration is reduced (removed) to 1 % approximately by appropriately maintaining the operating temperature and the water vapor ratio.

5 An example of an apparatus to which the reformed gas obtained above is to be fed is a polymer electrolyte fuel cell which is one type of fuel cell.

10 With this type of fuel cell, since it operates at a low temperature around about 80°C, if the reformed gas, as the fuel gas, contains carbon monoxide even by a trace amount (e.g. greater than several tens of ppm), its electrode catalyst is poisoned by the carbon monoxide, leading to significant deterioration in the cell performance. Therefore, it is necessary to reduce the carbon monoxide concentration in the fed reformed gas to less than several tens of ppm, more preferably to less than 10 ppm. In other words, the carbon monoxide concentration in the hydrogen-rich reformed gas needs to be reduced (removed) by a higher level than the conventional standard level (about 1%).

15 For the purpose of such relatively high level reduction of carbon monoxide, the method thus far has proposed the following methods.

20 (a) A CO remover having a metal catalysis is provided on the downstream of the reformer, so that with supply of air or oxygen as an oxidizing agent, carbon monoxide contained in the reformed gas is oxidized to be removed as carbon dioxide.

25 (b) A "methanator" is provided for causing reaction between hydrogen and carbon monoxide contained in the reformed gas, so that the carbon monoxide is reduced to be removed as methane.

Examples of the method (a) above include the following.

1. "The 2nd FCDIC Fuel Cell Symposium Lecture Proceedings: 235-240 (1995)". In this, air is mixed with the reformed gas so as to achieve: $[O_2]/[CO] = 3$. Then, as this mixture gas is caused to contact Ru catalyst, carbon monoxide in the reformed gas is selectively oxidized and removed.

2. Japanese laid-open patent gazette: No. Hei. 7-296837: "Reformed-Gas Supplying System". In this, a methanol fuel reforming system includes a methanol retriever disposed at the downstream of a methanol reformer and also includes a carbon-monoxide oxidation reactor (acting as a CO remover) charged with Pt-Rh catalyst disposed at the downstream of the methanol retriever, so as to oxidize and remove the carbon monoxide in a methanol reformed gas.

Examples of the art (b) above include the following.

1. Japanese laid-open patent gazette No. Hei. 6-283189: "Fuel-Cell Power Generating System". In this, on the downstream of a CO shift converter, there are disposed a CO_2 adsorber and methanator having an Ni catalyst, so that some of carbon dioxide contained in the reformed gas is adsorbed and removed at the CO_2 adsorber and then carbon monoxide and the remaining carbon dioxide are methanated by the metanator to be removed as methane.

However, the above-described methods respectively have the following problems.

(a) problem with oxidation removal

In order to sufficiently remove carbon monoxide, it is necessary to add oxygen by an amount greater than 6 chemical equivalent. Then, not only the carbon monoxide to be removed, a great amount of hydrogen which

can be a useful fuel will be lost by combustion.

(b) problem with removal using methanator

5 With this technique, if the treatment-object gas contains also carbon
dioxide as is the case with a reformed gas, methanation of carbon dioxide, in
addition to that of carbon monoxide, tends to occur with very high likelihood.
For this reason, if carbon monoxide is to be removed sufficiently while
restricting loss of hydrogen due to methanation of carbon dioxide, it is
10 necessary to first absorb and remove the carbon dioxide also present in the
reformed gas, so that the system required for this tends to be complicated.

DISCLOSURE OF THE INVENTION

15 The present invention has been made in order to solve the above-
described problems, and its object is to obtain a carbon-monoxide removing
technique capable of very effectively reducing/removing carbon monoxide
present at one thousand of ppm to several % in a hydrogen-rich treatment-
object gas such as a reformed gas obtained by reforming of a fuel such as
20 natural gas, methanol, etc. to a concentration of several tens of ppm
(preferably 10 ppm) or lower without excessive loss of hydrogen (with
minimizing the consumption of hydrogen), even when carbon dioxide,
methane are co-existent.

25 For accomplishing this object, according to characterizing features
of the present invention, a system for removing carbon monoxide from a
hydrogen-containing treatment-object gas comprises two stages of CO
removers for removing carbon monoxide, the first-stage CO remover
removing a portion of the carbon monoxide by methanation thereof through
a catalyst reaction, the second-stage CO remover removing the remaining
30 portion of the carbon monoxide mainly by oxidation thereof through a

further catalyst reaction involving addition of an oxidizing agent.

5 The carbon monoxide removing system of the invention includes two stages of first CO remover and second CO remover which are disposed in the mentioned order, so that the treatment-object gas containing carbon monoxide is fed first into the first CO remover and then into the second CO remover, whereby treatment-object gas having its carbon monoxide content removed is obtained from the second CO remover.

10 In the above, the removal of carbon monoxide by the first CO remover is methanation removal using catalyst reaction and that by the second CO remover is mainly oxidation removal using catalyst reaction involving addition of an oxidizing agent.

15 Accordingly, in this removing process, at the first CO remover, by using hydrogen present in the surrounding, methanation of carbon monoxide is promoted for removal of the carbon monoxide, so that no oxidizing agent is required. By this catalyst reaction, a major part (more than half) of carbon monoxide present in the treatment-object gas may be methanated to be removed.

20 Subsequently, at the second CO remover, the remaining portion of the carbon monoxide is removed mainly through oxidation thereof by a catalyst reaction involving addition of an oxidizing agent. In this case, since the amount of the carbon monoxide has already been reduced, the remaining amount of carbon monoxide can be substantially entirely removed (to a concentration of several ppm approximately, for instance) with restricting the amount of the oxidizing agent to be added to the treatment-object gas.

25 Therefore, with this carbon-monoxide removing system, it is possible to restrict the amount of the oxidizing agent required for the removal to be smaller than the equivalent of the carbon monoxide entering the first CO remover. As a result, treatment-object gas free from carbon monoxide may be obtained with limiting the amount of useful hydrogen to be consumed in the combustion.

30

Such removing system as described above may be applied as it is to a case where the treatment-object gas contains a certain amount (e.g. 20%) of carbon dioxide. This is a major characterizing feature of the present invention.

5 Preferably, in the carbon-monoxide removing system described above, the first CO remover includes a first metal catalyst comprising one or more kinds selected from the group consisting of Ru, Pt, Rh, Pd, etc and capable of methanating carbon monoxide and a first-catalyst reaction condition setting mechanism for maintaining a catalyst reaction layer of the
10 remover at a temperature required for methanation reaction of the carbon monoxide by the first metal catalyst; and

the second CO remover includes a second metal catalyst comprising one or more kinds selected from the group consisting of Ru, Pt, Rh, Pd, etc. and capable of oxidizing the carbon monoxide, a second-catalyst reaction
15 condition setting mechanism for maintaining a catalyst reaction layer of the remover at a temperature required for the oxidation reaction of the carbon monoxide by the second metal catalyst, and an oxidizing-agent supplying mechanism for supplying the oxidizing agent required for the oxidation reaction with adjustment of its addition amount.

20 With this system, both of the reaction at the first CO remover and that at the second CO remover involve metal catalysts, but different catalyst reaction from each other.

That is to say, at the first CO remover, the first metal catalyst is employed and the first-catalyst reaction condition setting mechanism is
25 provided for providing the catalyst reaction condition for causing the methanation thereof, whereby the methanation of carbon monoxide is promoted to ensure its treatment amount.

On the other hand, at the second CO remover, the oxidizing agent required for the oxidation of the carbon monoxide is supplied from the

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oxidizing-agent supplying mechanism and also with the second-catalyst

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reaction condition setting mechanism, the reaction between this oxidizing agent and the carbon monoxide is effected by the second metal catalyst. With these, the carbon monoxide, which has already been reduced to a relatively small amount, can be removed mainly through the oxidation by the second metal catalyst.

Now, if the above-described treatment is effected on a reformed gas (such gas is obtained by reforming fuel such as hydrocarbon such as natural gas, alcohol such as methanol, naphtha, kerosene, etc. , and usually contain hydrogen more than about 50% on the dry basis) to be supplied as a fuel gas to a fuel cell, the fuel cell can operate effectively by using the reformed gas from which carbon monoxide has been removed effectively. Hence, the present invention can be suitably applied especially to a solid polymer electrolyte fuel cell.

In the above, the construction of the carbon monoxide removing system of the invention has been described. Next, there will be described the invention's method of removing carbon monoxide using such system.

The method of removing carbon monoxide from a hydrogen-containing treatment-object gas, according to the present invention, is characterized by the following steps:

a) a first step of causing the treatment-object gas to contact a first metal catalyst capable of methanating carbon monoxide so that a portion of the carbon monoxide is removed through its methanation; and

b) a second step of causing the treatment-object gas from the first step together with an oxidizing agent to contact a second metal catalyst capable of oxidizing carbon monoxide so that the remaining portion of carbon monoxide is removed mainly through its oxidation.

In the above, the first step corresponds to the process effected at the first CO remover of the invention's carbon monoxide removing system described above and the second step corresponds to the process effected at the second CO remover of the same.

By the same operating principle as described hereinbefore in the foregoing section describing the system, with this carbon monoxide removing method, the treatment-object gas substantially free from carbon monoxide may be obtained, with minimizing the amount of the oxidizing agent required for removal so as to reduce the amount of useful hydrogen consumed in the combustion. And, this removal is possible to a concentration of several ppm or lower to several tens of ppm. Also, this removal is possible even when the treatment-object gas contains e.g. about 20% of carbon dioxide, without involving treatment of this component.

Preferably, in the first step, a reaction temperature of catalyst reaction between a first metal catalyst and the treatment-object gas is controlled to a temperature at which methanation of carbon monoxide may be promoted with restricting methanation of carbon dioxide, so as to reduce the carbon monoxide concentration of the treatment-object gas to be obtained from this step as much as possible. In this respect, it is especially preferred that the carbon monoxide concentration be reduced to 70% or lower, more preferably 50% or lower, most preferably 30% or lower of the original carbon concentration of the gas charged into this first step. For example, if it is reduced to 50% or lower, the amount of hydrogen loss in association with the CO oxidation at the second step can be reduced and also the amount of heat generated in association with the oxidation too can be reduced. As a result, the temperature control of the reactor becomes easier and the CO oxidation can be effected reliably.

With the catalyst having the methanating ability for carbon monoxide, methanation of carbon dioxide too tends to occur. Then, by restricting this reaction, the consumption of hydrogen may be reduced to the necessity minimum. Moreover, by reducing the concentration of carbon monoxide discharged from the first step to be smaller than a predetermined amount, it becomes possible to remove carbon monoxide through its oxidation at the second step easily and reliably and the amount of oxidizing

agent required may also be reduced.

Preferably, in the first step, a first metal catalyst comprising one or more kinds selected from the group consisting of Ru, Pt, Rh, Pd, is employed and a catalyst reaction layer is maintained at a temperature where methanation of carbon monoxide takes place by the first metal catalyst. This is because these catalysts are capable of methanation of carbon monoxide.

More particularly, it is preferred that the first metal catalyst be a high quantity metal supported catalyst comprising the one or more kinds selected from the group consisting of Ru, Pt, Rh, and Pd by 0.1 to 5 wt.% (more preferably 0.5 to 5 wt.%) supported on a catalyst support. In this if the metal content is lower than 0.1 wt.%, the methanation activity tends to be reduced. Whereas, if it exceeds 5 wt.%, no significant improvement in the methanation activity can be achieved.

Next, in the second step, a second metal catalyst comprising one or more kinds selected from the group consisting of Ru, Pt, Rh, and Pd is employed and a catalyst reaction portion is maintained at a temperature where oxidation of carbon monoxide takes place by the second metal catalyst involving addition of an oxidizing agent.

The catalysts, as described hereinbefore, cause methanation of carbon monoxide. But, at the same time, in the presence of a large amount of oxidizing agent (oxidizing atmosphere) and at a relatively low temperature, they act as catalysts for mainly oxidizing carbon monoxide. Accordingly, by using such metal as the second metal catalyst suitable for the object of the present invention, the reaction at its catalyst reaction layer is controlled to be limited to an oxidation reaction mainly. Whereby, the remaining portion of the carbon monoxide may substantially entirely be oxidized and removed.

More particularly, it is preferred that the second metal catalyst be a low quantity metal supported catalyst comprising the one or more kinds

selected from the group consisting of Ru, Pt, Rh, and Pd by 0.1 to 5 wt.% (more preferably 0.1 to 2 wt.%) supported on a catalyst support. In this if the metal content is lower than 0.1 wt.%, the oxidation activity tends to be reduced. Whereas, if it exceeds 5 wt.%, no significant improvement in the oxidation activity can be achieved.

Further, in the above-described treatment of carbon monoxide, preferably, the total amount of the oxidizing agent supplied at the second step be below 3 chemical equivalents in oxygen conversion relative to the amount of carbon monoxide originally contained in the treatment-object gas, more preferably below 2 chemical equivalents, most preferably below the chemical equivalent. In this case, the consumption amount of hydrogen may be reduced sufficiently.

Also preferably, a second-catalyst reaction temperature which is the catalyst reaction temperature at the second step is set to be lower than a first-catalyst reaction temperature which is the catalyst reaction temperature at the first step.

Temperature suitable for methanation exists in a relatively high temperature range. Then, in order to cause the oxidation mainly, this should take place at a temperature range lower than the above temperature range. In such case, no heating operation becomes necessary in particular.

Further, as described hereinbefore, preferably, the method of the invention is applied to a reformed gas.

In the present invention, basically, the first step utilizes methanation reaction and the second step utilizes oxidation reaction. Then, it is desirable that the amount of hydrogen consumed at the first step be minimized. Therefore, the present inventors have conducted intensive research and achieved the following invention.

Namely, in removing carbon monoxide from a hydrogen-containing treatment-object gas, the treatment-object gas is exposed to a first metal catalyst capable of methanating carbon monoxide so as to remove the carbon

monoxide as methane. In doing this, it is preferred that the methanation reaction be effected with setting the methanation reaction temperature higher than 160°C and lower than 240°C.

With this, by setting the temperature higher than a predetermined temperature (higher than 160°C), the methanation reaction will proceed to a certain degree, whereas by setting also this temperature lower than a predetermined temperature (lower than 240°C), it is possible to sufficiently restrict occurrence of methanation of carbon dioxide which tends to involve consumption of hydrogen. More preferably, the upper-limit temperature is set at 200°C.

In this case, such relatively low temperature range is employed for the methanation reaction. Therefore, it is preferred from the view point of catalyst reactivity, the first metal catalyst comprise catalyst containing Ru.

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is a view showing a first embodiment.

BEST MODE OF EMBODYING THE INVENTION

An example of mode of using a carbon-monoxide removing system according to the present invention will be described.

From a carbon-monoxide shift converter reactor, a treatment-object gas which contains a relatively large amount, i.e. about 6000 ppm to 1 wt.%, of carbon monoxide is guided to a first CO remover (incorporating a "high quantity metal supported catalyst"). Generally, this treatment-object gas contains no oxidizing component (oxygen).

Next, the treated treatment-object gas discharged from the first CO remover is guided to a second CO remover. In this second CO remover (incorporating a "low quantity metal supported catalyst"), to a trace amount

of carbon monoxide which remains un-removed at the first CO remover, air or oxygen alone is added as an oxidizing agent to obtain $[O_2] / [CO]$ ratio of 0.5 to 4.5 and then a reaction is carried out at a relatively low temperature range. In this, a CO sensor or the like may be provided between the second CO remover and the first CO remover so that the amount of oxidizing agent be controlled based on a detection value from this sensor.

The "high quantity metal supported catalyst" is a catalyst comprising 0.5 to 5 wt.% of one or more kinds of metal selected from the group consisting of Ru, Pt, Rh, and Pd supported on an alumina. The "low quantity metal supported catalyst" is a catalyst comprising 0.1 to 2 wt.% of one or more kinds of metal selected from the group consisting of Ru, Pt, Rh and Pd supported on an alumina support.

In each catalyst reaction, a value of GHSV (Gas Hourly Space Velocity: treatment-object gas flow amount/ catalyst volume (1/h)) is set to about 500 to 100000/h (set to a practically possible range). Further, the reaction temperature ($^{\circ}C$) at the first CO remover is set to a range from 155 to 300 $^{\circ}C$. Whereas, the reaction temperature at the second CO remover is set to a range from 50 to 250 $^{\circ}C$ lower than the reaction temperature at the first CO remover. That is, the former is set to be higher than the latter.

In the above, preferably, the reaction temperature of the first step at the first CO remover is set to 155 to 300 $^{\circ}C$ (more preferably, to 175 to 250 $^{\circ}C$). And, preferably, the reaction temperature of the second step at the second CO remover is set to a relatively lower range of 50 to 250 $^{\circ}C$ (more preferably, to 100 to 160 $^{\circ}C$). This is because the temperature range should differ in correspondence with each object.

If the temperature of the first step is lower than 155 $^{\circ}C$, the methanation activity tends to be lower. Whereas, if it is higher than 300 $^{\circ}C$, an influence of a side reaction tends to appear. Then, if the reaction

(incorporating a "low quantity metal supported catalyst"), to a trace amount of carbon monoxide which remains un-removed at the first CO remover, air or oxygen alone is added as an oxidizing agent to obtain $[O_2] / [CO]$ ratio of 0.5 to 4.5 and then a reaction is carried out at a relatively low temperature range. In this, a CO sensor or the like may be provided between the second CO remover and the first CO remover so that the amount of oxidizing agent be controlled based on a detection value from this sensor.

The "high quantity metal supported catalyst" is a catalyst comprising 0.5 to 5 wt.% of one or more kinds of metal selected from the group consisting of Ru, Pt, Rh, Pd and Ni supported on an alumina. The "low quantity metal supported catalyst" is a catalyst comprising 0.1 to 2 wt.% of one or more kinds of metal selected from the group consisting of Ru, Pt, Rh and Pd supported on an alumina.

In each catalyst reaction, a value of GHSV (Gas Hourly Space Velocity: treatment-object gas flow amount/ catalyst volume (1/h)) is set to about 500 to 100000/h (set to a practically possible range).

Further, the reaction temperature ($^{\circ}C$) at the first CO remover is set to a range from 155 to $300^{\circ}C$. Whereas, the reaction temperature at the second CO remover is set to a range from 50 to $250^{\circ}C$ lower than the reaction temperature at the first CO remover. That is, the former is set to be higher than the latter.

In the above, preferably, the reaction temperature of the first step at the first CO remover is set to 155 to $300^{\circ}C$ (more preferably, to 175 to $250^{\circ}C$). And, preferably, the reaction temperature of the second step at the second CO remover is set to a relatively lower range of 50 to $250^{\circ}C$ (more preferably, to 100 to $160^{\circ}C$). This is because the temperature range should differ in correspondence with each object.

If the temperature of the first step is lower than $155^{\circ}C$, the methanation activity tends to be lower. Whereas, if it is higher than $300^{\circ}C$, an influence of a side reaction tends to appear. Then, if the reaction

temperature is set to be lower than 250°C, methanation of carbon dioxide which is unnecessary in the present invention, can be restricted in particular. For achieving the restriction of methanation of carbon dioxide and promotion of methanation of carbon monoxide, an even more preferred range is a temperature range from 160°C to 240°C.

On the other hand, at the second step, if the temperature range is set to be relatively low (lower than 250°C), oxidation reaction will mainly take place, so that it becomes easier to reduce carbon monoxide to a sufficient level.

If the temperature of the second step is lower than 50°C, the reactivity will be low. Whereas, if it is higher than 250°C, it may happen that it becomes difficult to reduce carbon monoxide to be lower than several tens of ppm, due to a side effect such as a reverse-shift reaction (reverse water-gas shift reaction).

With the above arrangements, at the first CO remover, carbon monoxide is reacted with hydrogen in the treatment-object gas to be converted into methane at the relatively high temperature range according to a reaction formula: $\text{CO} + 3\text{H}_2 \rightarrow \text{CH}_4 + \text{H}_2\text{O}$, so that most of the carbon monoxide may be removed. This reaction can take place through appropriate control of the catalyst reaction temperature, substantially without aid of an oxidizing agent. In this case, the amount of carbon monoxide removable by the methanation reaction can be higher than 70% of that introduced into the first CO remover.

Next, at the second CO remover, mainly through a oxidation reaction involving an oxidizing agent according to a formula: $2\text{CO} + \text{O}_2 \rightarrow 2\text{CO}_2$, carbon monoxide is removed. This removal is possible to a level of several tens of ppm (preferably, 10 ppm) or lower. Hence, this may be suitably applied to a polymer electrolyte fuel cell.

Accordingly, for carbon monoxide contained in a treatment-object gas at a reaction outlet of a carbon monoxide shift converter, the

conventional method requires oxygen three times in the mole ratio, i.e. 6 chemical equivalents. On the other hand, according to the present invention, only with addition of air containing oxygen by a concentration lower than the chemical equivalent of the carbon monoxide, the carbon monoxide contained in the treatment-object gas may be removed. And, unnecessary consumption of hydrogen may be reduced correspondingly.

Further, even when air is selected as the oxidizing agent, the addition amount of air is small. Thus, the amount of nitrogen to be mixed into the treatment-object gas too can be reduced. Consequently, reduction in the partial pressure of the hydrogen in the treatment-object gas may be decreased.

By appropriate control of the reaction temperatures of the first CO remover and the second CO remover, it is possible to restrict such side reaction as: $\text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}$ or $\text{CO}_2 + \text{H}_2 \rightarrow \text{CO} + \text{H}_2\text{O}$, etc. So that, carbon monoxide may be removed very efficiently even when several tens of % of carbon dioxide is co-existent in the gas and the loss of hydrogen may be reduced.

The removing method of the invention is very suitable also for a case where methane is present in the treatment-object gas, since the method functions well in such case as well.

Further, comparing the reaction temperature of the first CO remover and the reaction temperature of the second CO remover to each other, the reaction temperature shifts from a high temperature to a low temperature along the flow passage.

Moreover, if the treatment-object gas is supplied to a low-temperature operating fuel cell such as a solid polymer electrolyte fuel cell by employing the method of the present invention, it is possible to supply fuel gas with lower efficiency reduction, by avoiding CO poisoning of the electrode catalyst of the fuel cell.

EMBODIMENTS

Fig. 1 shows a construction of a system according to a first embodiment of the present invention for removing carbon monoxide in a treatment-object gas. Fuel 1 consisting mainly of natural gas is introduced to a desulfurizer 2 to have its sulfur content removed. Next, this together with water vapor 3 is fed to a reformer 4 to be subjected to a reforming reaction. Subsequently, it is subjected to a carbon-monoxide shift reaction (water-gas shift reaction) at a carbon-monoxide transformer 5.

After this unit, there are disposed a first CO remover 6 and a second CO remover 7. To the second CO remover 7, air 8 is added as an oxidizing agent.

The first CO remover 6 is equipped with a first-catalyst reaction condition setting mechanism 6a for realizing a catalyst reaction condition at this remover suitable for this invention. This first-catalyst reaction condition setting mechanism 6a provides a flow control function for controlling the amount of reformed gas passing the remover 6 in relation with the amount of catalyst available and a temperature controlling function for controlling the reaction temperature, so that GHSV and the reaction temperature can be adjustably set. On the other hand, the second CO remover 7 is equipped with a second-catalyst reaction condition setting mechanism 7a which provides an equivalent function to the first-catalyst reaction condition setting mechanism 6a to the second remover 7. In general, in actual use, the SV value is fixed in a catalyst reaction. Therefore, the first-catalyst reaction condition setting mechanism 6a and the second-catalyst reaction condition setting mechanism 7a should be able to adjusting at least the temperature of the respective catalyst reaction portion.

The second CO remover 7 is further equipped with an oxidizing-agent adding mechanism 7b capable of adding an oxidizing agent with adjustment of its addition amount. The amount of this addition is set to be

an oxidizing-agent amount just sufficient for the oxidation in relation with the CO concentration of the reformed gas at the entrance of the second CO remover 7. Needless to say, the oxidizing agent should not be supplied excessively.

5 Next, modes of using this system will be described.

[first embodiment]

10 The first CO remover 6 was charged with catalyst (as a first metal catalyst and also as a high quantity metal supported catalyst) comprising 1 wt.% of ruthenium supported on granular alumina. Then, a reformed gas (humidified gas containing 6000 ppm of carbon monoxide, 5000 ppm of methane, 20% of carbon dioxide and 78.9% of hydrogen) obtained from the exit of carbon-monoxide shift converter 5 was introduced to this first CO
15 remover 6, in which a methanation reaction of CO was effected at GHSV 3750-15000/h and at a temperature of 200 to 230°C.

 Next, the second CO remover 7 was charged with catalyst (as a second metal catalyst and also as a low quantity metal supported catalyst) comprising 0.5 wt.% of ruthenium supported on granular alumina. The
20 reformed gas obtained from the exit of this first CO remover 6 was introduced to the second CO remover 7. In this, air 8 containing oxygen by an amount corresponding to a ratio of 1.5 of $[O_2] / [CO]$ relative to the CO concentration of the reformed gas at the entrance of the second CO remover
7 was added, so that CO oxidation was effected at GHSV15000/h
25 approximately and at 150°C.

The results are summarized and shown in Table 1 below.

Table 1

example	first CO remover temperature (°C)	SV value l/h	exit CO concentration (ppm)	exit CO concentration of second CO remover (ppm)
1	200	3750	353	0
2	200	5000	1627	0
3	210	5000	322	0
4	210	7500	1497	0
5	230	7500	223	0
6	230	15000	889	0

In the above, the CO concentration of the treatment-object gas introduced into the first CO remover was 6000 ppm. In the table above, as for the value "0" as the CO concentration, the detection limit of CO concentration was 5 ppm.

Now, the concentrations of methane formed at the first CO remover for the respective examples were as follows.

example	first CO remover temperature (°C)	exit CO concentration (ppm)	concentration of methane formed (ppm)
1	200	353	7013
2	200	1627	4483
3	210	322	7179
4	210	1497	4577
5	230	223	10145
6	230	889	10803

The results show that CO removal was possible in each case with an amount of oxygen (the amount of oxidizing agent) smaller than the chemical equivalent of the amount of carbon monoxide entering the first CO remover

[second embodiment]

The first CO remover 6 was charged with catalyst (as a first metal catalyst and also as a high quantity metal supported catalyst) comprising 2 wt.% of ruthenium supported on granular alumina. Then, a reformed gas (humidified gas containing 6000 ppm of carbon monoxide, 5000 ppm of methane, 20% of carbon dioxide and 78.9% of hydrogen) obtained from the exit of carbon-monoxide shift converter 5 was introduced to this first CO remover 6, in which a methanation reaction of CO was effected at GHSV 3750-5000/h and at a temperature of 220 to 260°C.

Next, the second CO remover 7 was charged with catalyst (as a second metal catalyst and also as a low quantity metal supported catalyst) comprising 1 wt.% of ruthenium supported on granular alumina. Then, the reformed gas from the exit of the first CO remover 6 was introduced to this second CO remover 7, in which with addition of air containing oxygen by an amount corresponding to $[O_2] / [CO]$ ratio of 1.3 relative to the CO concentration of the reformed gas at the entrance to this second CO remover 7, CO oxidation reaction was carried out at GHSV 15000/h approximately and at a temperature of 135°C.

The results are summarized and shown in Table 2 below.

Table 2

example	first CO remover temperature (°C)	SV value 1/h	exit CO concentration (ppm)	exit CO concentration of second CO remover (ppm)
1	220	3750	1021	0
2	220	5000	1510	0
3	240	3750	803	0
4	240	5000	965	0
5	260	5000	1053	0

In the above, the CO concentration of the treatment-object gas introduced into the first CO remover was 6000 ppm. In the table above, as for the value "0" shown as the CO concentration, the detection limit of CO concentration was 5 ppm.

In this example too, substantially same results as the above example were obtained regarding the methane formed.

The results show that CO removal was possible in each case with an amount of oxygen (the amount of oxidizing agent) smaller than the chemical equivalent of the amount of carbon monoxide entering the first CO remover 6.

As described above, after the carbon-monoxide shift converter 5, there are provided the two stages of CO removers, i.e. the first CO remover 6 and the second CO remover 7. At the first CO remover 6, a major portion of CO contained in reformed gas is removed through its methanation. At the second CO remover 7, the remaining portion of CO is removed through its oxidation with addition of a trace amount of oxidizing agent. Consequently, it was possible to remove carbon monoxide from reformed gas while significantly reducing the amount of oxidizing agent to be added.

[comparison example 1]

In this comparison example 1, catalyst comprising 2 wt.% of ruthenium supported on granular alumina was charged into a CO remover, into which a hydrogen balance gas having a carbon monoxide concentration of 6000 ppm, a carbon dioxide concentration of 20% and a methane concentration of 5000 ppm was added air containing 21% of oxygen (the ratio between gas and air: $[O_2] / [CO] = 2$ approximately), and then this mixture was introduced at GHSV 5000/h at the reaction temperature of 150°C. When oxidation removal alone was conducted under this condition, it was found that 33 ppm of CO remain un-removed.

[comparison example 2]

In this comparison example 2, catalyst comprising 2 wt.% of ruthenium supported on granular alumina was charged into a CO remover, into which a hydrogen balance gas having a carbon monoxide concentration of 6000 ppm, a carbon dioxide concentration of 20% and a methane concentration of 5000 ppm was introduced at GHSV 5000/h at the reaction temperature of 150°C. When the carbon monoxide removal by methanation was conducted under this condition, it was found that only about 100 ppm of the carbon monoxide was methanated.

[other modes of embodying the invention]

(a) In the foregoing embodiments, the system includes the desulfurizer 2 and the carbon monoxide shift converter 5. Depending on the kind of fuel, however, they system may eliminate these. That is to say, the present invention does not provide any limitations in the process of forming the reformed gas before the carbon monoxide removing system.

In the above respect, however, the reformed gas should contain hydrogen to be used as a fuel gas as its main component thereof (more than about 50% on the dry basis) and also carbon monoxide to be removed.

In general, such reformed gas hardly contains such components as oxygen which is an oxidizing agent component.

(b) In the foregoing embodiments, air and oxygen are cited as examples of the oxidizing agent. Alternatively, the oxidizing element may be any substance containing a certain component which can contribute to oxidation.

(c) In the foregoing embodiments, the first CO remover and the second

CO remover are provided separately from each other. Instead, it is possible to provide, as a construction for effecting the above-described process, a single-container construction housing a catalyst for methanation disposed on the upstream side in the flow direction of the treatment-object gas having catalyst for methanation, a catalyst for oxidation disposed on the downstream side in the same direction with a mechanism for introducing an oxidizing agent to this portion.

In such case, the upstream portion of the container corresponds to the first CO remover and the downstream portion thereof corresponds to the second CO remover.

(d) Other embodiments of the present invention will be described next.

[other embodiments]

The first CO remover 6 was charged with catalyst (as a first metal catalyst) comprising a granular alumina supporting 1 wt.% of rhodium. Then, a reformed gas (same as first and second embodiments) obtained from the exit of carbon-monoxide shift converter 5 was introduced to this first CO remover 6, in which a methanation reaction of CO was effected at GHSV 3750-7500/h and at a temperature of 260 to 300°C.

Next, the second CO remover 7 was charged with catalyst (as a second metal catalyst and also as a low quantity metal supported catalyst) comprising 1 wt.% of ruthenium supported on granular alumina. Then, the reformed gas from the exit of the first CO remover 6 was introduced to this second CO remover 7, in which with addition of air 8 containing oxygen by an amount corresponding to $[O_2] / [CO]$ ratio of 1.3 relative to the CO concentration of the reformed gas at the entrance to this second CO remover 7, CO oxidation reaction was carried out at GHSV 15000/h approximately and at a temperature of 135°C.

The results are summarized and shown in Table 3 below.

Table 3

example	first CO remover temperature (°C)	SV value l/h	exit CO concentration (ppm)	exit CO concentration of second CO remover (ppm)
1	260	3750	1502	0
2	280	7500	1753	0
3	280	5000	728	0
4	300	7500	552	0
5	300	5000	217	0

In the above, the CO concentration of the treatment-object gas introduced into the first CO remover was 6000 ppm. In the table above, as for the value "0" shown as the CO concentration, the detection limit of CO concentration was 5 ppm.

In this example too, substantially same results as the above example were obtained regarding the methane formed.

The results show that rhodium can be used also.

Further, by using the combination shown in the second embodiment of the first CO remover 6 comprising the ruthenium catalyst and the second CO remover 7 comprising the ruthenium catalyst and under the conditions of example 1 (the example shown as example 1 in Table 2), the catalyst of the second CO remover 7 was replaced by 0.5 wt.% of platinum supported on granular alumina (an example of second metal catalyst). Then, the system was operated.

The operating conditions of the second CO remover 7 were: the catalyst reaction temperature 170°C; GHSV 30000 and the addition amount of air: $[O_2] / [CO] = 2.7$. With these, the carbon monoxide concentration was reduced to 0 ppm (below the actual detection limit). Therefore, platinum

can be employed in the second CO remover in this invention.

Further, by using the combination shown in the first alternate embodiment of the first CO remover 6 comprising the rhodium catalyst and the second CO remover 7 comprising the ruthenium catalyst and under the conditions of example 5 (the example shown as example 5 in Table 3), the catalyst of the second CO remover 7 was replaced by 1 wt.% of rhodium supported on granular alumina (an example of second metal catalyst). Then, the system was operated.

The operating conditions of the second CO remover 7 were: the temperature 250°C; GHSV 15000 and the addition amount of air: $[O_2] / [CO] = 4$. With these, in this case too, the carbon monoxide concentration at the exit of the second CO remover 7 was reduced to 0 ppm (below the actual detection limit). Therefore, rhodium can be employed in the second CO remover in this invention.

EFFECT OF THE INVENTION

According to the present invention, the amount of oxidizing agent such as air or oxygen to be added in the course of removal of carbon monoxide from a reformed gas can be reduced significantly. Thus, CO removal of reformed gas is possible with minimizing loss of hydrogen by combustion.

Further, since in a fuel cell system methane produced by methanation of carbon monoxide can be used as a fuel for a burner of the reformer, it is possible to improve high efficiency of the system.

For this reason, it is possible to feed a fuel reformed gas with high efficiency to a low-temperature operating type fuel cell such as polymer electrolyte fuel cell using a fuel such as natural gas, methanol, etc.

Since the above-described method of the present invention allows efficient removal of carbon monoxide with a relatively high GHSV, the

method provides the advantage of allowing the CO removers to be formed compact.

What is claimed is:

1. (amended) A system for removing carbon monoxide from a hydrogen-containing treatment-object gas;

5 wherein the system comprises two stages of CO removers for removing carbon monoxide, the first-stage CO remover removing a portion of the carbon monoxide by methanation thereof through a catalyst reaction by a first metal catalyst comprising one or more kinds selected from the group consisting of Ru, Pt, Rh, and Pd and capable of methanating carbon
10 the carbon monoxide, the second-stage CO remover removing the remaining portion of the carbon monoxide mainly by oxidation thereof through a further catalyst reaction involving addition of an oxidizing agent.

2. (amended) The system for removing carbon monoxide, according to
15 claim 1, wherein the first CO remover includes the first metal catalyst and a first catalyst reaction condition setting mechanism for maintaining a catalyst reaction layer of the remover at a temperature required for methanation reaction of the carbon monoxide by the first metal catalyst; and
the second CO remover includes a second metal catalyst capable of
20 oxidizing the carbon monoxide, a second catalyst reaction condition setting mechanism for maintaining a catalyst reaction layer of the remover at a temperature required for the oxidation reaction of the carbon monoxide by the second metal catalyst, and an oxidizing-agent supplying mechanism for supplying the oxidizing agent required for the oxidation reaction with
25 adjustment of its addition amount.

3. The system for removing carbon monoxide, according to claim 1 or 2,
wherein said treatment-object gas is a reformed gas obtained by reforming of
fuel such as hydrocarbon, alcohol, naphtha, kerosene to be supplied as a fuel
30 gas to a fuel cell.

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4. (amended) A method of removing carbon monoxide from a hydrogen-containing treatment-object gas comprising:

a first step of causing the treatment-object gas to contact a first metal catalyst comprising one or more kinds selected from the group consisting of Ru, Pt, Rh, and Pd and capable of methanating carbon monoxide at a temperature where methanation of carbon monoxide takes place by the first metal catalyst so that a portion of the carbon monoxide is removed through its methanation; and

a second step of causing the treatment-object gas from the first step together with an oxidizing agent to contact a second metal catalyst capable of oxidizing carbon monoxide so that the remaining portion of carbon monoxide is removed mainly through its oxidation.

5. The method of removing carbon monoxide, according to claim 4, wherein in the first step, a reaction temperature of catalyst reaction between the first metal catalyst and the treatment-object gas is controlled to a temperature at which methanation of carbon monoxide may be promoted with restricting methanation of carbon dioxide, so as to reduce the carbon monoxide concentration of the treatment-object gas to 50% or lower of the original carbon monoxide concentration of the gas charged into this first step.

6. (amended) The method of removing carbon monoxide, according to claim 4 or 5, wherein in the second step, the second metal catalyst comprising one or more kinds selected from the group consisting of Ru, Pt, Rh and Pd is employed and

in the second step, a catalyst reaction layer is maintained at a temperature where oxidation of carbon monoxide takes place by the second metal catalyst involving addition of an oxidizing agent.

7. The method of removing carbon monoxide, according to claim 4, 5
or 6, wherein the total amount of the oxidizing agent supplied at the second
step is below 3 chemical equivalents in oxygen conversion relative to the
amount of carbon monoxide originally contained in the treatment-object gas
introduced in the first step.

8. The method of removing carbon monoxide, according to claim 4, 5
or 6, wherein the total amount of the oxidizing agent supplied at the second
step is below the chemical equivalent in oxygen conversion relative to the
amount of carbon monoxide originally contained in the treatment-object gas
introduced in the first step.

9. The method of removing carbon monoxide, according to any one of
claims 4-8, wherein said hydrogen-containing treatment-object gas
comprises a reformed gas supplied to a fuel cell as a fuel gas.

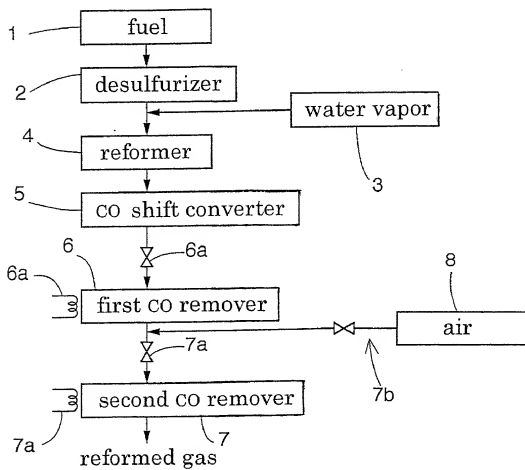
10. (canceled)

11. (canceled)

ABSTRACT OF THE DISCLOSURE

The object of the present invention is to obtain a carbon-monoxide removing technique capable of very effectively reducing/removing carbon
5 monoxide present at one thousand of ppm to several % in a hydrogen-rich
treatment-object gas such as a reformed gas obtained by reforming of a fuel
such as natural gas, methanol, etc. to a concentration of several tens of ppm
(preferably 10 ppm) or lower without excessive loss of hydrogen, even when
carbon dioxide, methane are co-existent. For accomplishing this object,
10 there are provided two stages of CO removers for removing carbon monoxide
from a hydrogen-containing treatment-object gas, the first-stage CO remover
removing a portion of the carbon monoxide by methanation thereof through
a catalyst reaction, the second-stage CO remover removing the remaining
portion of the carbon monoxide mainly by oxidation thereof through a
15 further catalyst reaction involving addition of an oxidizing agent.

Fig. 1



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I believe I am the original, first and sole inventor (if only one name
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names are listed below) of the subject matter which is claimed and
for which a patent is sought on the invention entitled

SYSTEM AND METHOD FOR REMOVING

CARBON MONOXIDE

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☒ was filed on March 5, 1999
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PCT/JP99/01083 and was amended on
January 4, 2000 (if applicable).

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I hereby state that I have reviewed and understand the contents of
the above identified specification, including the claims, as
amended by any amendment referred to above.

私は、送付規則第37編第1条56項に定義されると
おり、特許資格の有無について重要な情報を開示する義務が
あることを認めます。

I acknowledge the duty to disclose information which is material to
patentability as defined in Title 37, Code of Federal Regulations,
Section 1.56.

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Japanese Language Declaration

(日本語宣言書)

私は、米国法典第35編第119条(a)-(d)項又は365条(b)項に基き下記の、米国以外の国の少なくとも一つを指定している特許協力条約365(a)項に基き国際出願、又は外国での特許出願もしくは発明者証の出願についての外国優先権をここに主張するとともに、優先権を主張している、本出願の前に出願された特許または発明者証の外国出願を以下に、枠内をマークすることで、示しています。

Prior Foreign Application(s)

外国での先行出願

(Number) (番号)	(Country) (国名)
(Number) (番号)	(Country) (国名)

I hereby claim foreign priority under Title 35, United States Code, Section 119 (a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Priority Not Claimed

優先権主張なし

(Day/Month/Year Filed) (出願年月日)
(Day/Month/Year Filed) (出願年月日)

私は、第35編米国法典第119条(e)項に基いて下記の米国特許出願規定に記載された権利をここに主張いたします。

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below.

(Application No.) (出願番号)	(Filing Date) (出願日)
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(Application No.) (出願番号)	(Filing Date) (出願日)
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私は、下記の特許出願に記載された権利、又は米国を指定している特許協力条約365条(c)に基き権利をここに主張します。また、本出願の各種求願書の内容が米国法典第35編第112条第1項又は特許協力条約で規定された方法で先行する米国特許出願に開示されていない限り、その先行米国出願書提出日以降で本出願書の日本国内または特許協力条約国際提出日までの期間中に入手された、連邦規則法典第37条1章56項で定義された特許資格の有無に関する重要な情報について開示義務があることを認識しています。

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s), or 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code Section 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of application.

(Application No.) (出願番号)	(Filing Date) (出願日)
-----------------------------	------------------------

(Status: Patented, Pending, Abandoned) (状況: 特許許可済、係属中、放棄済)

(Application No.) (出願番号)	(Filing Date) (出願日)
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(Status: Patented, Pending, Abandoned) (状況: 特許許可済、係属中、放棄済)

私は、私自身の知識に基いて本宣言書中で私が行なう表明が真実であり、かつ私の入手した情報と私の信じるところに基き表明が全て真実であると信じていること、さらに故意になされた虚偽の表明及びそれと同等の行は米国法典第18編第1001条に基き、罰金または拘禁、もしくはその両方により処罰されること、そしてそのような故意による虚偽の表明を行なえば、出願した、又は既に許可された特許の有効性が失われることを認識し、よってここに上記のごとく宣誓を致します。

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Japanese Language Declaration

(日本語宣言書)

委任状: 私は下記の発明者として、本出願に関する一切の
 手続を米特許商標局に対して遂行する弁護士または代理人
 として、下記の者を指名いたします。(弁護士、または代理
 人の氏名及び登録番号を明記のこと)

POWER OF ATTORNEY: As a named inventor, I hereby appoint
 the following attorney(s) and/or agent(s) to prosecute this
 application and transact all business in the Patent and Trademark
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(第三以降の共同発明者についても同様に記載し、署名をす
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(Supply similar information and signature for third and subsequent
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(日本語宣誓書) Japanese Language Declaration

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日付		
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第五共同発明者	Full name of 5th joint inventor, if any	
発明者の署名	5th inventor's signature	Date
日付		
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国籍	Citizenship	
私書箱	Post Office Address	
第六共同発明者	Full name of 6th joint inventor, if any	
発明者の署名	6th inventor's signature	Date
日付		
住所	Residence	
国籍	Citizenship	
私書箱	Post Office Address	